

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

32860-000283/US

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

**10 / 070607**

INTERNATIONAL APPLICATION NO.

PCTDE00/03078

INTERNATIONAL FILING DATE

September 6, 2000

PRIORITY DATE CLAIMED

September 10, 1999

TITLE OF INVENTION

METHOD FOR PRODUCING AN OPTICAL GRATING ON AN OPTICAL CONDUCTOR AND DEVICE COMPRISING A GRATING OF THIS TYPE

APPLICANT(S) FOR DO/EO/US

Manfred ROTHARDT and Michael WILLSCH

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau). WO 01/20377 A1
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is transmitted herewith.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-1449 and International Search Report (PCT/ISA/210) in German with twenty (20) references and German Translation Aid.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
  - 1) ~~Two~~ 2 sheetsof Formal Drawings

JC13 Rec'd PCT/PTO 08 MAR 2002

U.S. APPLICATION NO (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO		ATTORNEY'S DOCKET NUMBER	
NEW 10/070607		PCTDE00/03078		32860-000283/US	

<p>21. <input checked="" type="checkbox"/> The following fees are submitted.</p> <p><b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):</b>          Neither international preliminary examination fee (37 CFR 1.482)          nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO          and International Search Report not prepared by the EPO or JPO. . . . . <b>\$1,040.00</b></p> <p>International preliminary examination fee (37 CFR 1.482) not paid to          USPTO but International Search Report prepared by the EPO or JPO . . . . . <b>\$890.00</b></p> <p>International preliminary examination fee (37 CFR 1.482) not paid to USPTO          but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. . . . . <b>\$710.00</b></p> <p>International preliminary examination fee (37 CFR 1.482) paid to USPTO          but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . . <b>\$690.00</b></p> <p>International preliminary examination fee (37 CFR 1.482) paid to USPTO          and all claims satisfied provisions of PCT Article 33(1)-(4). . . . . <b>\$100.00</b></p> <p style="text-align: right;"><b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b></p> <p>Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30          months from the earliest claimed priority date (37 CFR 1.492(e)).</p> <table border="1" style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <th style="width: 20%;">CLAIMS</th> <th style="width: 20%;">NUMBER FILED</th> <th style="width: 20%;">NUMBER EXTRA</th> <th style="width: 20%;">RATE</th> <th style="width: 20%;"></th> <th style="width: 20%;"></th> </tr> <tr> <td>Total Claims</td> <td>6 - 20 =</td> <td>0</td> <td>X \$18.00</td> <td>\$</td> <td>0</td> </tr> <tr> <td>Independent Claims</td> <td>2 - 3 =</td> <td>0</td> <td>X \$80.00</td> <td>\$</td> <td>0</td> </tr> <tr> <td colspan="3">MULTIPLE DEPENDENT CLAIM(S) (if applicable)</td> <td>None</td> <td>+ \$270.00</td> <td>\$ 0</td> </tr> <tr> <td colspan="4" style="text-align: right;"><b>TOTAL OF ABOVE CALCULATIONS =</b></td> <td>\$</td> <td><b>1,020.00</b></td> </tr> </table> <p><input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are          reduced by 1/2.</p> <p style="text-align: right;"><b>SUBTOTAL =</b></p> <table border="1" style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td>Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30          months from the earliest claimed priority date (37 CFR 1.492(f)).</td> <td>\$</td> <td>0</td> </tr> <tr> <td style="text-align: right;"><b>TOTAL NATIONAL FEE =</b></td> <td>\$</td> <td><b>1,020.00</b></td> </tr> </table> <p>Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be          accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property +</p> <p style="text-align: right;"><b>TOTAL FEES ENCLOSED =</b></p> <table border="1" style="width:100%; border-collapse: collapse; font-size: small;"> <tr> <td rowspan="2"></td> <td style="text-align: right;">Amount to be: refunded</td> <td>\$</td> </tr> <tr> <td style="text-align: right;">charged</td> <td>\$</td> </tr> </table>	CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE			Total Claims	6 - 20 =	0	X \$18.00	\$	0	Independent Claims	2 - 3 =	0	X \$80.00	\$	0	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			None	+ \$270.00	\$ 0	<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$	<b>1,020.00</b>	Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).	\$	0	<b>TOTAL NATIONAL FEE =</b>	\$	<b>1,020.00</b>		Amount to be: refunded	\$	charged	\$	<p><b>CALCULATIONS</b></p> <p><b>PTO USE ONLY</b></p>
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a. ☒ A check in the amount of \$ **1,020.00** to cover the above fees is enclosed.

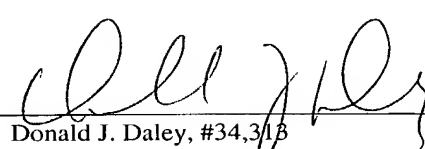
b. ☐ Please charge my Deposit Account. No. 08-0750 in the amount of \$            to cover the above fees.  
 A triplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
 overpayment to Deposit Account No. 08-0750.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
 • 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

Send all correspondence to  
**Harness, Dickey & Pierce, P.L.C – Customer No. 30596**  
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**Reston, Virginia 20195**

**Date: MARCH 8, 2002**

By   
 Donald J. Daley, #34,313

PATENT  
32860-000283/US

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Manfred ROTHARDT and Michael WILLSCH  
Int'l App. No. PCT/DE00/03078  
Application No.: NEW  
Filed: March 8, 2002  
For: METHOD FOR PRODUCING AN OPTICAL GRATING ON AN  
OPTICAL CONDUCTOR AND DEVICE COMPRISING A  
GRATING OF THIS TYPE

**PRELIMINARY AMENDMENT**

Assistant Commissioner for Patents  
Washington, DC 20231

March 8, 2002

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

**IN THE ABSTRACT**

Please replace the Abstract with the attached revised Abstract.

**IN THE CLAIMS**

Please amend the claims as follows:

1. (Amended) A method for producing at least one optical grating on an optical conductor, comprising:

durably fixing the conductor at least at two fixing points, arranged at a distance from one another; and

producing the grating on the fixed conductor between the fixing points.

2. (Amended) The method as claimed in claim 1, wherein the optical conductor is stress-free between the fixing points during the production of the grating.

3. (Amended) The method as claimed in claim 1, wherein the optical conductor is stressed between the fixing points during the production of the grating.

4. (Amended) An arrangement, comprising:

a carrier body;

an elongated optical conductor; and

an optical grating, wherein the conductor is fixed at least at two fixing points arranged at a distance from one another, on the carrier body, wherein the grating is formed on the fixed conductor between the fixing points, wherein the conductor is durably fixed on the carrier body at the fixing points, and wherein the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

**Please add the following new claims:**

-- 5. The method of claim 1, wherein the at least one optical grating is a Bragg grating.

6. The arrangement of claim 4, wherein the optical grating is a Bragg grating. --

**REMARKS**

Claims 1-6 are now present in this application, with new claims 5 and 6 being added by the present Preliminary Amendment. It should be noted that the amendments to original claims 1-4 of the present application are non-narrowing amendments, made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations. For example, amendments have been made to broaden the claims;

remove reference numerals in the claims; remove the European phrase “characterized in that”; remove multiple dependencies in the claims; and to place claims in a more recognizable U.S. form, including the use of the transitional phrase “comprising” as well as the phrase “wherein”. Other such non-narrowing amendments include placing apparatus-type claims (setting elements forth in separate paragraphs) and method claims (setting forth elements in separate paragraphs beginning with “-ing” verbs) in a more recognizable U.S. form. Again, all amendments are non-narrowing and have been made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations.

#### **SUBSTITUTE SPECIFICATION**

In accordance with 37 C.F.R. §1.125, a substitute specification has been included in lieu of substitute paragraphs in connection with the present Preliminary Amendment. The substitute specification is submitted in clean form, attached hereto, and is accompanied by a marked-up version showing the changes made to the original specification. The changes have been made in an effort to place the specification in better form for U.S. practice. No new matter has been added by these changes to the specification. Further, the substitute specification includes paragraph numbers to facilitate amendment practice as requested by the U.S. Patent and Trademark Office.

#### **CONCLUSION**

Accordingly, in view of the above amendments and remarks, an early indication of the allowability of each of claims 1-6 in connection with the present application is earnestly

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Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Donald J. Daley at the telephone number of the undersigned below.

Respectfully submitted,

HARNESS, DICKEY & PIERCE, P.L.C

Donald J. Daley, Reg. No. 34,313

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ABSTRACT OF THE DISCLOSURE

An optical Bragg grating is produced on an optical fiber, the fiber being fixed at two fixing points, arranged at a distance from one another. The grating is then produced on the fixed fiber between the fixing points, with the special feature that the fiber is durably fixed at the fixing points before the grating is produced.

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METHOD FOR PRODUCING AN OPTICAL GRATING ON AN OPTICAL  
CONDUCTOR AND DEVICE COMPRISING A GRATING OF THIS TYPE

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE00/03078 which has an International filing date of September 6, 2000, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to a method for producing at least one optical grating, in particular a Bragg grating, on an optical conductor. The conductor is preferably fixed at least at two fixing points, which are arranged at a distance from one another. The grating is then preferably produced on the fixed conductor between the fixing points.

Background of the Invention

[0003] In known methods of the aforementioned type, the optical conductor is a glass fiber which is prestressed between the two fixing points during the production of the grating and is released again after the production of the grating on the fiber.

[0004] An optical Bragg grating was first produced using a standing optical wave of the radiation of an argon laser in an optical monomode fiber (see K.O. Hill et al.: "Photosensitivity in optical fiber waveguides: Application to reflection filter fabrication", Appl. Phys. Lett., vol. 32, 1978, pp 647 - 649). This produces relatively long fiber gratings with a length of, for example, about one meter.

[0005] Later it was proposed to produce a Bragg grating in a fiber by transverse UV irradiation of an optical fiber. In this case, a holographic method was used in which the superposition of two beams of UV radiation with plane waves generated an interference fringe pattern which was used to expose the fiber.

[0006] The two beams of UV radiation can be generated in different ways. The following arrangements have already been used:

- an interferometer with splitter mirror and three or more deflection mirrors (see G. Meltz, W.W. Morey, W.H. Glenn: "Formation of Bragg gratings in optical fibers by transverse holographic method", Opt. Lett. 14 (15), 1989, p 823);
- a mirror (Lloyd's mirror interferometer, see R. Kasyap et al.: "All-fiber narrow-band reflection gratings at 1550 nm", Electron. Lett. 26 (12), 1990, p 823 and/or B. Eggleton, P.A. Krug, L. Poladin: "Dispersion compensation by using Bragg grating filters with self induced chirp", Tech. Digest. Opt. Fib. Comm. Conf., OFC'94, 1994, p 227);



- a prism (Lloyd's prism interferometer, see Q. Zhang et al.: "Simple prism-based scheme for fabricating Bragg gratings in optical fibers", Opt. Lett. 19 (23), 1994, pp 2030 - 2032 and/or N.H. Rizvi, M.C. Gower: "Production of submicron period Bragg gratings in optical fibers using wavefront division with a biprism and an excimer laser source", Appl. Phys. Lett. 67 (6), 1995, pp 739 - 741);

- an interferometer with diffraction-optical beam splitter and two deflection mirrors;
- total reflection in a quartz glass body (see R. Kashap et al.: "A novel method of writing photo-induced chirped Bragg gratings in optical fibers", Electron. Lett. 12, 1994, pp 994 - 997).

[0007] Another known method includes the use of a phase mask for producing an interference fringe pattern (see K.O. Hill et al.: "Bragg gratings fabricated in photosensitive optical fiber by UV exposure through a phase mask", Appl. Phys. Lett. Vol. 62, 1993, pp 1035 -1037 and/or D.Z. Anderson et al.: "Production of in-fiber gratings using a diffractive optical element", Electron. Lett., vol. 29, 1993, pp 566 - 568). In this case, the fiber is fixed directly behind a phase mask made of quartz glass. A beam of UV radiation is sent through the phase mask. The UV radiation is diffracted at a grating structure of the phase mask. A plus first order of diffraction and a minus first order of diffraction are produced behind the grating structure of the phase mask. Superposition of the two orders of diffraction results in a UV interference fringe pattern. The fiber is irradiated by the fringe pattern. On account of the photosensitivity of the fiber, a periodic increase in refractive index arises in the irradiated regions of the fiber core.

[0008] A further method for producing a grating on a fiber is point by point exposure of the fiber (see K.O. Hill et al.: "Efficient mode conversion in telecommunication fiber using externally written gratings", Electron. Lett. 26 (16), 1990, p 1270 and/or B. Malo et al.: "Point by point fabrication of micro-Bragg gratings in photosensitive fiber using single excimer laser pulse refractive index modification techniques", Electron. Lett. Vol. 29, 1993, pp 1668 - 1669). In this case, it is important that the fiber does not experience any changes in its mechanical state during the relatively long time required for writing the grating into the fiber.

[0009] A general overview of the methods used heretofore can be found for example in K.O. Hill et al.: "Fiber Bragg Grating Technology Fundamentals and Overview", Journal of Lightwave Technology, Vol. 15, No. 8, August 1997, pp 1263 - 1276.

[0010] B. Malo et al.: "Apodised in-fiber Bragg grating reflectors photoimprinted using a phase mask", Electron. Lett., vol. 31, 1995, pp 223 - 224 and/or J. Albert et al.: "Apodisation of the spectral response of fiber Bragg gratings using a phase mask with variable diffraction efficiency", Electron. Lett., vol. 31, 1995, pp 222 - 223, disclose producing fiber gratings with exactly defined requirements imposed on the spectral properties by means of

apodisation; in this case, too, the fiber is initially restrained and is released again after the grating has been written into the fiber.

#### SUMMARY OF THE INVENTION

[0011] It is an object of an embodiment of the invention to show how an optical grating, in particular a Bragg grating, can be produced on an optical conductor in a simple manner. The grating may have an exactly defined and uniform grating constant.

[0012] This object can be achieved by, for example, an optical conductor durably fixed at the fixing points before the grating is produced. This is in contrast to the known methods in which a fiber is restrained before the grating is produced or written. It can be fixedly held prestressed to a greater or lesser extent during the writing process, and can be released again after the grating has been written, so that the fiber is only fixed temporarily rather than durably.

[0013] An embodiment of the invention is based on the insight that the procedure used heretofore of restraining and subsequently releasing the fiber after the production of the grating on the fiber device that mechanical stresses which persisted during said production are liberated again, or that new mechanical stresses are generated through handling of the fiber after release. These mechanical stresses lead to changes in the grating constant or period in the grating and thus to variation of the reflection or transmission spectrum. Mechanical stresses which act only in parts of the grating and, accordingly, influence only portions of the grating structure can drastically alter the spectral profile and thus call into question the usability of the relevant grating.

[0014] Undesired partial alterations of the grating constant also play a major part in a grating with exactly defined requirements imposed on the spectral properties, for example in a grating produced by apodisation or a particularly long fiber grating. In this case, too, such undesired partial alterations may be brought about by the fact that, during the production of such a grating, the fiber is firstly restrained and is released again after the production of the grating.

[0015] A method according to an embodiment of the invention advantageously ensures the stability of the grating constant and of all other parameters of the grating after the production of the grating on the optical conductor.

[0016] In one embodiment of the method according to the invention, the optical conductor is stress-free between the fixing points during the production of the grating. In another embodiment, the optical conductor is tensioned between the fixing points during the production of the grating.

[0017] An embodiment of the invention also provides an advantageous arrangement having a carrier body, an optical conductor and an optical grating, in particular a Bragg grating. The conductor can be fixed at least at two fixing points, which are arranged at a distance from one

another, on the carrier body. The grating can be formed on the fixed conductor between the fixing points. The conductor can be durably fixed on the carrier body at the fixing points, and the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The invention is explained in more detail by way of example embodiments in the description below, with reference to the drawings, in which:

Figures 1a to 1d show a starting stage, two intermediate stages and an end stage of an exemplary embodiment of the method according to an embodiment of the invention,

Figures 2a and 2b show, in side view and plan view, respectively, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring a temperature,

Figure 3 shows, in plan view, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring an acceleration, and

Figure 4 shows, in side view, a temperature-stable Bragg reference grating produced by the method according to an embodiment of the invention.

[0019] The figures are diagrammatic and not to scale.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] In accordance with the starting stage of the method according to the invention and indicated in figure 1a, an optical conductor 1 is applied to a carrier body 2, which is illustrated in each case in side view in figures 1a to 1d, and is durably fixed at two fixing points 21, 21, which are arranged at a distance  $d$  from one other in the direction of a defined longitudinal axis 10 of the conductor 1, on the carrier body 2. This thereby produces the first intermediate stage of the method according to the invention as indicated in figure 1b.

[0021] On the conductor 1 thus fixed, an optical grating 11 (see figure 1d) is produced between the two fixing points 21, 21. To that end, it is possible to use, for example, any of the methods described in the prior art. By way of example, in accordance with figure 1c, the photosensitive conductor 1 is exposed with a beam of radiation 4, for example comprising UV light, sent through a phase mask 3. The radiation 4 impinging as a plane optical wave 41 on the mask 3 is diffracted at a grating structure 31 of the phase mask 3. Downstream of the grating structure 31 of the phase mask 3, a plus first order 32 of diffraction and a minus first order 33 of diffraction are produced, each of which respectively defines an interference fringe and which, taken together, form an interference fringe pattern 35. This fringe pattern 35 exposes the conductor 1 between the fixing points 21, 21 in such a way that the interference fringes defined by the borders 32 and 33 of diffraction periodically succeed one another in

the direction of the longitudinal axis 10 of the conductor 1. On account of the photosensitivity of the conductor 1, a respective increase in refractive index arises in each exposing interference fringe.

[0022] After this exposure of the conductor 1, the end stage of the method according to the invention as illustrated in figure 1d has been produced, in which the optical grating 11 is formed between the two fixing points 21, 21 of the carrier body 2 on the conductor 1. The optical grating is defined by local refractive index increases 110 which periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1.

[0023] A particular advantage of the described use of the phase mask 3 is to be seen in the fact that the phase mask 3 can be applied directly on the carrier body 2 and, unlike before, the conductor 1 in the form of the glass fiber need not be brought into position at a distance before the phase mask 3. Moreover, this procedure advantageously ensures a very precise position of a Bragg wavelength and of the other parameters of the grating 11, for example a spectral width, a degree of reflection, etc. of the grating 11. It is advantageous that, since the grating 11 is already fixed by a carrier body 2, these parameters no longer have to be set subsequently during installation.

[0024] In this way, it is also possible to produce two or more optical gratings 11 on the conductor 1 between the two fixing points 21, 21, to be precise at the same time and/or one after the other in time and/or spatially separate from one another and/or superposed on one another.

[0025] The fixing of the conductor 1 on the carrier body 2 at the two fixing points 21, 21 remains even after the production of the one or more gratings 11 and is not detached.

[0026] The optical conductor 1 is durably fixed on the carrier body 2 not subsequently but actually before the production of the one or more optical gratings 11.

[0027] The optical conductor 1 that is to be fixed on the carrier body 2 preferably does not yet have an optical grating, although at least one grating which is different from a grating 11 to be produced first may already be present on said conductor 1, but in that case it does not have the advantageous properties of the grating 11.

[0028] The optical conductor 1 is preferably an optical glass fiber, for example a monomode or multimode fiber and/or a core-cladding-glass fiber. The conductor 1 may also be an optical waveguide integrated on a substrate. The optical conductor 1 is preferably of elongate design in the direction of the longitudinal axis 10.

[0029] The optical conductor 1 can be held between the two the fixing points 21, 21 in such a way that it is stress-free during the production of a grating 11 between the fixing points 21. Preferably, the conductor 1 is freely suspended between the fixing points 21, 21 and the grating 11 is produced in the freely suspended conductor 1.

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**[0030]** It is also expedient if the optical conductor 1 is stressed between the two fixing points 21, 21 during the production of the grating 11. Such prestressing is expedient because, as a result, the conductor 1 still remains extended even in the event of a mechanical load relief acting on it.

**[0031]** The carrier body 2 may be designed not only for fixing the conductor 1, but also for realizing specific functions.

**[0032]** If the carrier body 2 serves only for fixing the conductor 1, it may be of simple, for example integral, design. By contrast, if it has to fulfil specific further functions, for example functions of a Bragg grating sensor, the carrier body 2 may be of more complicated, in particular composite, construction. Thus, by way of example, mechanical levers, actuators or elements having characteristic thermal expansion coefficients for temperature compensation may be part of the carrier body 2.

**[0033]** A particular advantage of the method according to the invention is that the conductor 1 can be connected to the carrier body 2, for example by bonding, soldering, collapsing, etc., without special consideration being given to conductor stress, room temperature and subsequently desired grating parameters of the grating 11. In the case of a conductor 1 in the form of a quartz glass fiber, for example, a temperature required for fixing the conductor 1 on the carrier body may be up to 800°C, while a grating 11 to be produced after this fixing is already degraded from approximately 150°C and is even destroyed at higher temperatures. After the fixing of the conductor 1 on the carrier body 2 at a higher temperature, all that need be done is to wait until the temperature of the conductor 1 has fallen to below the temperature from which degradation or deformation of the grating 11 to be produced occurs.

**[0034]** The method according to an embodiment of the invention advantageously makes it possible generally to realize Bragg grating sensors for measuring a physical quantity, including, for example, a sensor for measuring a temperature, an acceleration, a force, an electrical current, an electric voltage, an electric field, a magnetic field, etc., and also, for example, a stable Bragg grating as optical wavelength reference, an accurate Bragg grating for application in telecommunications and/or a long period optical grating (Long Period Grating (LPG)) and applications thereof.

**[0035]** Figures 2a and 2b illustrate, in side view and plan view, respectively, an exemplary Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring a temperature, figure 3 illustrates, in plan view, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring an acceleration, and figure 4 illustrates, in side view, a temperature-stable Bragg grating produced by the method according to an embodiment of the invention as an optical wavelength reference.

[0036] Each of the two sensors and also the temperature-stable Bragg grating in each case has an arrangement having a carrier body 2, an elongate optical conductor 1 and a Bragg grating 11, the conductor 1 being fixed at two fixing points 21, 21, which are arranged at a distance  $d$  from one another, on the carrier body 2, and the grating 11 being formed on the fixed conductor 1 between said fixing points 21, 21, with the special feature that the conductor 1 is durably fixed on the carrier body 2 at the fixing points 21, 21, and the grating 11 is a grating which is produced after the durable fixing of the conductor 1 on the carrier body 2.

[0037] In the case of the sensor according to figures 2a and 2b, the carrier body 2 is preferably in one piece and is composed of quartz glass, for example. The conductor 1 is, for example, a glass fiber which is fixed durably to the body 2 between the two fixing points 21, 21, preferably under prestressing, and in which the Bragg grating 11 is formed between the two fixing points 21, 21. The glass fiber 1 is freely suspended between the two fixing points 21, 21. To that end, the carrier body 2 has a cutout 20 on its side facing the glass fiber 1, said cutout being bridged by the fiber 1. A temperature-dependent change in refractive index and expansion of the fiber 1 leads to a measurable shift in the Bragg wavelength of the grating 11 with the temperature. The expansion of the fiber 1 with the temperature can be amplified by a suitably chosen material of the carrier body 2.

[0038] The arrangement of the sensor according to figure 3 differs from that of the sensor according to figures 2a and 2b essentially only through the presence of an inertial mass  $M$ . Otherwise, the sensor according to figure 3 structurally corresponds to the sensor according to figures 2a and 2b, and parts which are identical in both sensors are designated in figure 3 by the same reference symbols as in figures 2a and 2b.

[0039] In the sensor according to figure 3, the mass  $M$  is connected to the fiber 1 and exerts an expanding and/or contracting force on the Bragg grating 11, formed on the fiber 1, when the carrier body 2 is moved under acceleration.

[0040] In the case of the arrangement of the temperature-stable Bragg grating according to figure 4, the carrier body 2 is of composite rather than integral design. The composite carrier body 2 has a substrate body 2' and two sub-carrier bodies 2'', 2'' which are fixed on the substrate body 2' and separated from one another by an interspace 22'. On the two sub-carrier bodies 2'', 2'', the conductor 1, likewise comprising a glass fiber for example, is fixed at the two fixing points 21, 21 in such a way that one fixing point 21 is situated on one sub-carrier body 2'' and the other fixing point 21 is situated on the other sub-carrier body 2'', that the conductor 1 bridges the interspace 22', and that the grating 11 formed on the conductor 1 is arranged above the interspace 22'.

[0041] The two sub-carrier bodies 2'', 2'' are fixed on the substrate body 2' in such a way that a section 20'', 20'' - adjoining the interspace 22' - of each sub-carrier body 2'', 2'' is not

connected to the substrate body 2' and can freely expand and/or contract in the event of a change in temperature relative to the substrate body 2'.

[0042] The material of the substrate body 2' and the material of the two sub-carrier bodies 2", 2" are coordinated with one another in such a way that the interspace 22' between the sub-carrier bodies 2", 2" is narrowed and/or widened on account of a temperature-dictated expansion and/or contraction of the sections 20", 20" of the two sub-carrier bodies 2", 2". By way of example, the sub-carrier bodies 2", 2" are composed of a material having a thermal expansion coefficient  $\alpha > 0$  and the substrate body 2' is composed of a material having a smaller thermal expansion coefficient relative to said coefficient  $\alpha$ , preferably a vanishingly small thermal expansion coefficient.

[0043] A narrowing of the interspace 22' brought about by a change in temperature counteracts an expansion of the conductor 1 and hence of the grating 11 brought about by the change in temperature. A widening of the interspace 22' brought about by a change in temperature counteracts a contraction of the conductor 1 and hence of the grating 11 brought about by the change in temperature.

[0044] The material of the substrate body 2', the material of the two sub-carrier bodies 2", 2" and the material of the conductor 1 are preferably coordinated with one another in such a way that the narrowing of the interspace 22' brought about by a change in temperature essentially exactly cancels the expansion of the conductor 1 and hence of the grating 11 brought about by the change in temperature, and the widening of the interspace 22' brought about by a change in temperature essentially exactly cancels the contraction of the conductor 1 and hence of the grating 11 brought about by the change in temperature.

[0045] This is the case, for example, if the material of the sub-carrier bodies 2", 2" and the material of the conductor 1 essentially have the same thermal expansion coefficient  $\alpha > 0$  and if the thermal expansion coefficient of the material of the substrate body 2' is vanishingly small relative to said coefficient  $\alpha$ .

[0046] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

MARKED-UP SPECIFICATION

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Description

Method for producing an optical grating on an optical conductor and <sup>Device comprising</sup> arrangement having such a grating and <sup>of this type</sup> ~~such a conductor~~

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(PCT/DEW/03072) 5  
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FIELD OF THE INVENTION

The invention <sup>generally</sup> relates ~~according to the preamble of~~ claim 1, to a method for producing at least one optical grating, in particular a Bragg grating, on an optical conductor. The conductor <sup>is preferably</sup> being fixed at least at two fixing points, which are arranged at a distance from one another, and the grating <sup>is preferably</sup> then being produced on the fixed conductor between ~~said~~ <sup>the</sup> fixing points.

BACKGROUND OF THE INVENTION

In known methods of the aforementioned type, the optical conductor is a glass fiber which is prestressed between the two fixing points during the production of the grating and is released again after the production of the grating on the fiber.

20

An optical Bragg grating was first produced <sup>using</sup> ~~by means of~~ a standing optical wave of the radiation of an argon laser in an optical monomode fiber (see K.O. Hill et al.: "Photosensitivity in optical fiber waveguides: Application to reflection filter fabrication", Appl. Phys. Lett., vol. 32, 1978, pp 647 - 649). This produces relatively long fiber gratings with a length of, for example, about one meter.

25

Later it was proposed to produce a Bragg grating in a fiber by transverse UV irradiation of an optical fiber. In this case, a holographic method <sup>was</sup> ~~is~~ used in which the superposition of two beams of UV radiation with plane waves generated an interference fringe pattern which <sup>was</sup> ~~is~~ used to expose the fiber.

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The two beams of UV radiation can be generated in different ways. The following arrangements have already been used:

- 5 - an interferometer with splitter mirror and three or more deflection mirrors (see G. Meltz, W.W. Morey, W.H. Glenn: "Formation of Bragg gratings in optical fibers by transverse holographic method", Opt. Lett. 14 (15), 1989, p 823);
- 10 - a mirror (Lloyd's mirror interferometer, see R. Kashap et al.: "All-fiber narrow-band reflection gratings at 1550 nm", Electron. Lett. 26 (12), 1990, p 823 and/or B. Eggleton, P.A. Krug, L. Poladin:
- 15 "Dispersion compensation by using Bragg grating filters with self induced chirp", Tech. Digest. Opt. Fib. Comm. Conf., OFC'94, 1994, p 227);
- 20 - a prism (Lloyd's prism interferometer, see Q. Zhang et al.: "Simple prism-based scheme for fabricating Bragg gratings in optical fibers", Opt. Lett. 19 (23), 1994, pp 2030 - 2032 and/or N.H. Rizvi, M.C. Gower:
- 25 "Production of submicron period Bragg gratings in optical fibers using wavefront division with a biprism and an excimer laser source", Appl. Phys. Lett. 67 (6), 1995, pp 739 - 741);
- an interferometer with diffraction-optical beam splitter and two deflection mirrors;
- 30 - total reflection in a quartz glass body (see R. Kashap et al.: "A novel method of writing photo-induced chirped Bragg gratings in optical fibers", Electron. Lett. 12, 1994, pp 994 - 997).

35

Another known method <sup>includes</sup> ~~consists in~~ the use of a phase mask for producing an interference fringe pattern (see K.O. Hill et al.: "Bragg gratings fabricated in

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photosensitive optical fiber by UV exposure through a  
phase mask", Appl. Phys. Lett. Vol. 62, 1993, pp 1035 -  
1037

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and/or D.Z. Anderson et al.: "Production of in-fiber gratings using a diffractive optical element", Electron. Lett., vol. 29, 1993, pp 566 - 568). In this case, the fiber is fixed directly behind a phase mask made of quartz glass. A beam of UV radiation is sent through the phase mask. The UV radiation is diffracted at a grating structure of the phase mask. A plus first order of diffraction and a minus first order of diffraction are produced behind the grating structure of the phase mask. Superposition of the two orders of diffraction results in a UV interference fringe pattern. The fiber is irradiated by ~~said~~ <sup>the</sup> fringe pattern. On account of the photosensitivity of the fiber, a periodic increase in refractive index arises in the irradiated regions of the fiber core.

A further method for producing a grating on a fiber is point by point exposure of the fiber (see K.O. Hill et al.: "Efficient mode conversion in telecommunication fiber using externally written gratings", Electron. Lett. 26 (16), 1990, p 1270 and/or B. Malo et al.: "Point by point fabrication of micro-Bragg gratings in photosensitive fiber using single excimer laser pulse refractive index modification techniques", Electron. Lett. Vol. 29, 1993, pp 1668 - 1669). In this case, it is important that the fiber does not experience any changes in its mechanical state during the relatively long time required for writing the grating into the fiber.

A general overview of the methods used heretofore can be found for example in K.O. Hill et al.: "Fiber Bragg Grating Technology Fundamentals and Overview", Journal of Lightwave Technology, Vol. 15, No. 8, August 1997, pp 1263 - 1276.

B. Malo et al.: "Apodised in-fiber Bragg grating reflectors photoimprinted using a phase mask", Electron. Lett., vol. 31, 1995, pp 223 - 224 and/or

[illegible]

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An embodiment of the invention is based on the insight that the procedure used heretofore of restraining and subsequently releasing the fiber after the production of the grating on the fiber ~~means~~ <sup>device</sup> that mechanical stresses which persisted during said production are liberated again, or that new mechanical stresses are generated through handling of the fiber after release. These mechanical stresses lead to changes in the grating constant or period in the grating and thus to variation of the reflection or transmission spectrum. Mechanical stresses which act only in parts of the grating and, accordingly, influence only portions of the grating structure can drastically alter the spectral profile and thus call into question the usability of the relevant grating.

Undesired partial alterations of the grating constant also play a major part in a grating with exactly defined requirements imposed on the spectral properties, for example in a grating produced by apodisation or a particularly long fiber grating. In this case, too, such undesired partial alterations may be brought about by the fact that, during the production of such a grating, the fiber is firstly restrained and is released again after the production of the grating.

10 ~~The~~ <sup>An embodiment of</sup> method according to the invention advantageously ensures the stability of the grating constant and of all other parameters of the grating after the production of the grating on the optical conductor.

15 In one embodiment of the method according to the invention, the optical conductor is stress-free between the fixing points during the production of the grating<sup>?</sup> and. In another embodiment, the optical conductor is  
20 tensioned between the fixing points during the production of the grating.

<sup>An embodiment of the</sup>  
~~The~~ invention also provides an advantageous arrangement having a carrier body, an optical conductor and an  
25 optical grating, in particular a Bragg grating<sup>?</sup>. The conductor <sup>can be</sup> being fixed at least at two fixing points, which are arranged at a distance from one another, on the carrier body<sup>?</sup> and <sup>can be</sup> the grating <sup>being</sup> formed on the fixed conductor between <sup>the</sup> said fixing points<sup>?</sup> and which  
30 ~~arrangement is characterized in that~~ <sup>can be</sup> the conductor is durably fixed on the carrier body at the fixing points, and the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

### 35 BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in more detail by way of example <sup>embodiment</sup> in the description below, with reference to the drawings, in which:

Figures 1a to 1d show a starting stage, two intermediate stages and an end stage of an exemplary embodiment of the method according to <sup>an embodiment of</sup> the invention,

5

Figures 2a and 2b show, in side view and plan view, respectively, a Bragg grating sensor produced by the method according to <sup>an embodiment of</sup> the invention and serving for measuring a temperature,

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Figure 3 shows, in plan view, a Bragg grating sensor produced by the method according to <sup>an embodiment of</sup> the invention and serving for measuring an acceleration, and

15

Figure 4 shows, in side view, a temperature-stable Bragg reference grating <sup>an embodiment of</sup> produced by the method according to the invention.

20

The figures are diagrammatic and not to scale.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the starting stage of the method according to the invention and indicated in figure 1a, an optical conductor 1 is applied to a carrier body 2, which is illustrated in each case in side view in figures 1a to 1d, and is durably fixed at two fixing points 21, 21, which are arranged at a distance d from one other in the direction of a defined longitudinal axis 10 of the conductor 1, on the carrier body 2. <sup>This</sup> thereby <sup>produces</sup> ~~producing~~ the first intermediate stage of the method according to the invention as indicated in figure 1b.

30

On the conductor 1 thus fixed, an optical grating 11 (see figure 1d) is produced between the two fixing points 21, 21. To that end, it is possible to use, for example, any of the methods described in the prior art.

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By way of example, in accordance with figure 1c, the  
photosensitive conductor 1 is exposed with a beam of  
radiation 4, for example comprising UV light, sent  
through a phase mask 3. The radiation 4 impinging as a  
5 plane optical wave 41 on the mask 3



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is diffracted at a grating structure 31 of the phase mask 3. Downstream of the grating structure 31 of the phase mask 3, a plus first order 32 of diffraction and a minus first order 33 of diffraction are produced, each of which respectively defines an interference fringe and which, taken together, form an interference fringe pattern 35. This fringe pattern 35 exposes the conductor 1 between the fixing points 21, 21 in such a way that the interference fringes defined by the borders 32 and 33 of diffraction periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1. On account of the photosensitivity of the conductor 1, a respective increase in refractive index arises in each exposing interference fringe.

After this exposure of the conductor 1, the end stage of the method according to the invention as illustrated in figure 1d has been produced, in which the optical grating 11 is formed between the two fixing points 21, 21 of the carrier body 2 on the conductor 1. <sup>The said</sup> optical grating <sup>is</sup> ~~being~~ defined by local refractive index increases 110 which periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1.

A particular advantage of the described use of the phase mask 3 is to be seen in the fact that the phase mask 3 can be applied directly on the carrier body 2 and, unlike before, the conductor 1 in the form of the glass fiber need not be brought into position at a distance before the phase mask 3. Moreover, this procedure advantageously ensures a very precise position of a Bragg wavelength and of the other parameters of the grating 11, for example a spectral width, a degree of reflection, etc. of the grating 11. It is advantageous that, since the grating 11 is already fixed by a carrier body 2, these parameters no

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longer have to be set subsequently during installation.

In this way, it is also possible to produce two or more  
optical gratings 11 on the conductor 1 between the two  
5 fixing points 21, 21, to be precise at the same time

and/or one after the other in time and/or spatially separate from one another and/or superposed on one another.

- 5 The fixing of the conductor 1 on the carrier body 2 at the two fixing points 21, 21 remains even after the production of the one or more gratings 11 and is not detached.
- 10 The optical conductor 1 is durably fixed on the carrier body 2 not subsequently but actually before the production of the one or more optical gratings 11.

The optical conductor 1 that is to be fixed on the carrier body 2 preferably does not yet have an optical grating, although at least one grating which is different from a grating 11 to be produced first may already be present on said conductor 1, but in that case it does not have the advantageous properties of the grating 11.

The optical conductor 1 is preferably an optical glass fiber, for example a monomode or multimode fiber and/or a core-cladding-glass fiber. The conductor 1 may also be an optical waveguide integrated on a substrate. The optical conductor 1 is preferably of elongate design in the direction of the longitudinal axis 10.

The optical conductor 1 can be held between the two the fixing points 21, 21 in such a way that it is stress-free during the production of a grating 11 between the fixing points 21. Preferably, the conductor 1 is freely suspended between the fixing points 21, 21 and the grating 11 is produced in the freely suspended conductor 1.

It is also expedient if the optical conductor 1 is ~~stressed~~ <sup>stressed</sup> between the two fixing points 21, 21 during the production of the grating 11. Such prestressing is

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expedient because, as a result, the conductor 1 still remains extended even in the event of a mechanical load relief acting on it.

The carrier body 2 may be designed not only for fixing the conductor 1, but also for realizing specific functions.

5 If the carrier body 2 serves only for fixing the conductor 1, it may be of simple, for example integral, design. By contrast, if it has to fulfil specific further functions, for example functions of a Bragg grating sensor, the carrier body 2 may be of more  
10 complicated, in particular composite, construction. Thus, by way of example, mechanical levers, actuators or elements having characteristic thermal expansion coefficients for temperature compensation may be part of the carrier body 2.

15

A particular advantage of the method according to the invention is that the conductor 1 can be connected to the carrier body 2, for example by bonding, soldering, collapsing, etc., without special consideration being  
20 given to conductor stress, room temperature and subsequently desired grating parameters of the grating 11. In the case of a conductor 1 in the form of a quartz glass fiber, for example, a temperature required for fixing the conductor 1 on the carrier body may be up to  
25 800°C, while a grating 11 to be produced after this fixing is already degraded from approximately 150°C and is even destroyed at higher temperatures. After the fixing of the conductor 1 on the carrier body 2 at a higher temperature, all that need be done is to wait  
30 until the temperature of the conductor 1 has fallen to below the temperature from which degradation or deformation of the grating 11 to be produced occurs.

*an embodiment of*  
The method according to) the invention advantageously  
35 makes it possible generally to realize Bragg grating sensors for measuring a physical quantity, including, for example, a sensor for measuring a temperature, an acceleration, a force, an electrical current, an

[illegible]

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electric voltage, an electric field, a magnetic field,

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etc., and also, for example, a stable Bragg grating as optical wavelength reference, an accurate Bragg grating for application in telecommunications and/or a long period optical grating (Long Period Grating (LPG)) and applications thereof.

Figures 2a and 2b illustrate, in side view and plan view, respectively, an exemplary Bragg grating sensor produced by the method according to <sup>an embodiment of</sup> the invention and serving for measuring a temperature, figure 3 illustrates, in plan view, a Bragg grating sensor produced by the method according to <sup>an embodiment of</sup> the invention and serving for measuring an acceleration, and figure 4 illustrates, in side view, a temperature-stable Bragg grating produced by the method according to <sup>an embodiment of</sup> the invention as an optical wavelength reference.

Each of the two sensors and also the temperature-stable Bragg grating in each case has an arrangement having a carrier body 2, an elongate optical conductor 1 and a Bragg grating 11, the conductor 1 being fixed at two fixing points 21, 21, which are arranged at a distance d from one another, on the carrier body 2, and the grating 11 being formed on the fixed conductor 1 between said fixing points 21, 21, with the special feature that the conductor 1 is durably fixed on the carrier body 2 at the fixing points 21, 21, and the grating 11 is a grating which is produced after the durable fixing of the conductor 1 on the carrier body 2.

In the case of the sensor according to figures 2a and 2b, the carrier body 2 is preferably in one piece and is composed of quartz glass, for example. The conductor 1 is, for example, a glass fiber which is fixed durably to the body 2 between the two fixing points 21, 21, preferably under prestressing, and in which the Bragg grating 11 is formed between the two fixing points 21,

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21. The glass fiber 1 is freely suspended between the two fixing points 21, 21. To that end,





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the interspace 22'.

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The two sub-carrier bodies 2'', 2'' are fixed on the substrate body 2' in such a way that a section 20'', 20'' - adjoining the interspace 22' - of each sub-carrier body 2'', 2'' is not connected to the  
5 substrate body 2' and can freely expand and/or contract in the event of a change in temperature relative to the substrate body 2'.

The material of the substrate body 2' and the material  
10 of the two sub-carrier bodies 2'', 2'' are coordinated with one another in such a way that the interspace 22' between the sub-carrier bodies 2'', 2'' is narrowed and/or widened on account of a temperature-dictated expansion and/or contraction of the sections 20'', 20''  
15 of the two sub-carrier bodies 2'', 2''. By way of example, the sub-carrier bodies 2'', 2'' are composed of a material having a thermal expansion coefficient  $\alpha > 0$  and the substrate body 2' is composed of a material having a smaller thermal expansion coefficient  
20 relative to said coefficient  $\alpha$ , preferably a vanishingly small thermal expansion coefficient.

A narrowing of the interspace 22' brought about by a change in temperature counteracts an expansion of the  
25 conductor 1 and hence of the grating 11 brought about by said change in temperature. A widening of the interspace 22' brought about by a change in temperature counteracts a contraction of the conductor 1 and hence of the grating 11 brought about by said change in  
30 temperature.

The material of the substrate body 2', the material of the two sub-carrier bodies 2'', 2'' and the material of the conductor 1 are preferably coordinated with one  
35 another in such a way that the narrowing of the interspace 22' brought about by a change in temperature essentially exactly cancels the expansion of the conductor 1 and hence of the grating 11 brought about

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by <sup>the</sup>~~said~~ change in temperature, and the widening of the interspace 22' brought about by a change in temperature essentially exactly cancels the contraction of the conductor 1 and hence of the grating 11 brought about  
5 by <sup>the</sup>~~said~~ change in temperature.

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This is the case, for example, if the material of the sub-carrier bodies 2'', 2'' and the material of the conductor 1 essentially have the same thermal expansion coefficient  $\alpha > 0$  and if the thermal expansion coefficient of the material of the substrate body 2' is vanishingly small relative to said coefficient  $\alpha$ .

VARIATIONS  
of

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What is claimed is:

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durably fixing

~~Patent claims~~

1 (Amended)

1. A method for producing at least one optical grating (11), in particular a Bragg grating, on an optical conductor (1) <sup>comprising:</sup> [the conductor (1) being fixed] at least at two fixing points (21, 21), which are arranged at a distance (d) from one another; and <sup>producing</sup> the grating (11) is then produced on the fixed conductor (1) between <sup>the</sup> said fixing points (21, 21), characterized in that the conductor (1) is durably fixed at the fixing points (21, 21) before the grating (11) is produced.

points (21,  
(Amended)  
2 The m

2. (Amended) The method as claimed in claim 1, [characterized in that] <sup>wherein</sup> the optical conductor (1) is stress-free between the fixing points (21, 21) during the production of the grating (11).

3. *(Amended)* The me

3. ~~There is~~ The method as claimed in claim 1, characterized in that the optical conductor  $(1)$  is stressed between the fixing points  $(21, 21)$  during the production of the grating  $(11)$ .

(Amended)

4. An arrangement [having] comprising:

(-) a carrier body (2);

(- ) an elongated optical conductor (1); and

[ - ] an optical grating (11), in particular a Bragg grating, wherein

(-) the conductor (1) being fixed at least at two fixing points (21, 21), which are arranged at a distance (d)

from one another, on the carrier body (2), and wherein

(-) the grating (11) being <sup>is</sup> formed on the fixed conductor (1) between said <sup>the</sup> fixing points (21, 21), characterized in that ~~and~~ <sup>wherein</sup>

the conductor (1) is durably fixed on the carrier body (2) at the fixing points (21, 21), and wherein

[ - ] the grating (11) is a grating which is produced after the durable fixing of the conductor (1) on the carrier body (2).

- NEW
5. The method of claim 1, wherein the at least one optical grating is a Bragg grating.
  6. The arrangement of claim 4, wherein the optical grating is a Bragg grating.

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MARKED-UP ABSTRACT

Abstract

~~Method for producing an optical grating on an optical conductor and arrangement having such a grating and such a conductor~~

~~Method for producing~~ <sup>is produced</sup> An optical Bragg grating ~~(11)~~ on an optical fiber ~~(11)~~, the fiber being fixed at two fixing points ~~(21, 21)~~, ~~which are~~ arranged at a distance ~~(d)~~ from one another, <sup>and</sup> ~~the grating (11)~~ <sup>the</sup> ~~is then being~~ produced on the fixed fiber between ~~said~~ fixing points, with the special feature that the fiber is durably fixed at the fixing points before the grating is produced. ~~An arrangement having such a grating and such a fiber is specified.~~

~~Figure 1d~~



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2/ppts

Description

Method for producing an optical grating on an optical  
conductor and arrangement having such a grating and  
5 such a conductor

The invention relates, according to the preamble of  
claim 1, to a method for producing at least one optical  
grating, in particular a Bragg grating, on an optical  
10 conductor, the conductor being fixed at least at two  
fixing points, which are arranged at a distance from  
one another, and the grating then being produced on the  
fixed conductor between said fixing points.

15 In known methods of the aforementioned type, the  
optical conductor is a glass fiber which is prestressed  
between the two fixing points during the production of  
the grating and is released again after the production  
of the grating on the fiber.

20 An optical Bragg grating was first produced by means of  
a standing optical wave of the radiation of an argon  
laser in an optical monomode fiber (see K.O. Hill et  
al.: "Photosensitivity in optical fiber waveguides:  
25 Application to reflection filter fabrication", Appl.  
Phys. Lett., vol. 32, 1978, pp 647 - 649). This  
produces relatively long fiber gratings with a length  
of, for example, about one meter.

30 Later it was proposed to produce a Bragg grating in a  
fiber by transverse UV irradiation of an optical fiber.  
In this case, a holographic method is used in which the  
superposition of two beams of UV radiation with plane  
waves generates an interference fringe pattern which is  
35 used to expose the fiber.

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The two beams of UV radiation can be generated in different ways. The following arrangements have already been used:

- 5 - an interferometer with splitter mirror and three or more deflection mirrors (see G. Meltz, W.W. Morey, W.H. Glenn: "Formation of Bragg gratings in optical fibers by transverse holographic method", Opt. Lett. 14 (15), 1989, p 823);
- 10 - a mirror (Lloyd's mirror interferometer, see R. Kashap et al.: "All-fiber narrow-band reflection gratings at 1550 nm", Electron. Lett. 26 (12), 1990, p 823 and/or B. Eggleton, P.A. Krug, L. Poladin:
- 15 "Dispersion compensation by using Bragg grating filters with self induced chirp", Tech. Digest. Opt. Fib. Comm. Conf., OFC'94, 1994, p 227);
- a prism (Lloyd's prism interferometer, see Q. Zhang
- 20 et al.: "Simple prism-based scheme for fabricating Bragg gratings in optical fibers", Opt. Lett. 19 (23), 1994, pp 2030 - 2032 and/or N.H. Rizvi, M.C. Gower: "Production of submicron period Bragg gratings in optical fibers using wavefront division with a biprism
- 25 and an excimer laser source", Appl. Phys. Lett. 67 (6), 1995, pp 739 - 741);
- an interferometer with diffraction-optical beam splitter and two deflection mirrors;
- 30 - total reflection in a quartz glass body (see R. Kashap et al.: "A novel method of writing photo-induced chirped Bragg gratings in optical fibers", Electron. Lett. 12, 1994, pp 994 - 997).

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Another known method consists in the use of a phase mask for producing an interference fringe pattern (see K.O. Hill et al.: "Bragg gratings fabricated in

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photosensitive optical fiber by UV exposure through a phase mask", Appl. Phys. Lett. Vol. 62, 1993, pp 1035 - 1037

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and/or D.Z. Anderson et al.: "Production of in-fiber gratings using a diffractive optical element", Electron. Lett., vol. 29, 1993, pp 566 - 568). In this case, the fiber is fixed directly behind a phase mask  
 5 made of quartz glass. A beam of UV radiation is sent through the phase mask. The UV radiation is diffracted at a grating structure of the phase mask. A plus first order of diffraction and a minus first order of diffraction are produced behind the grating structure  
 10 of the phase mask. Superposition of the two orders of diffraction results in a UV interference fringe pattern. The fiber is irradiated by said fringe pattern. On account of the photosensitivity of the fiber, a periodic increase in refractive index arises  
 15 in the irradiated regions of the fiber core.

A further method for producing a grating on a fiber is point by point exposure of the fiber (see K.O. Hill et al.: "Efficient mode conversion in telecommunication  
 20 fiber using externally written gratings", Electron. Lett. 26 (16), 1990, p 1270 and/or B. Malo et al.: "Point by point fabrication of micro-Bragg gratings in photosensitive fiber using single excimer laser pulse refractive index modification techniques", Electron.  
 25 Lett. Vol. 29, 1993, pp 1668 - 1669). In this case, it is important that the fiber does not experience any changes in its mechanical state during the relatively long time required for writing the grating into the fiber.

30 A general overview of the methods used heretofore can be found for example in K.O. Hill et al.: "Fiber Bragg Grating Technology Fundamentals and Overview", Journal of Lightwave Technology, Vol. 15, No. 8, August 1997, pp 1263 - 1276.

35 B. Malo et al.: "Apodised in-fiber Bragg grating reflectors photoimprinted using a phase mask", Electron. Lett., vol. 31, 1995, pp 223 - 224 and/or

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J. Albert et al.: "Apodisation of the spectral response of fiber Bragg gratings using a phase mask with variable diffraction efficiency",

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Electron. Lett., vol. 31, 1995, pp 222 - 223, disclose producing fiber gratings with exactly defined requirements imposed on the spectral properties by means of apodisation; in this case, too, the fiber is initially restrained and is released again after the grating has been written into the fiber.

It is an object of the invention to show how an optical grating, in particular a Bragg grating, can be produced on an optical conductor in a simple manner, said grating having an exactly defined and uniform grating constant.

This object is achieved by means of the features specified in claim 1.

According to this solution, the optical conductor is durably fixed at the fixing points before the grating is produced, in contrast to the known methods in which a fiber is restrained before the grating is produced or written, is fixedly held prestressed to a greater or lesser extent during the writing process and is released again after the grating has been written, so that the fiber is only fixed temporarily rather than durably.

The invention is based on the insight that the procedure used heretofore of restraining and subsequently releasing the fiber after the production of the grating on the fiber means that mechanical stresses which persisted during said production are liberated again, or that new mechanical stresses are generated through handling of the fiber after release. These mechanical stresses lead to changes in the grating constant or period in the grating and thus to variation of the reflection or transmission spectrum. Mechanical stresses which act only in parts of the grating and, accordingly, influence only portions of the grating structure can drastically alter the spectral profile and thus call into question the usability of the relevant grating.

Undesired partial alterations of the grating constant also play a major part in a grating with exactly defined requirements imposed on the spectral properties, for example in a grating produced by apodisation or a particularly long fiber grating. In this case, too, such undesired partial alterations may be brought about by the fact that, during the production of such a grating, the fiber is firstly restrained and is released again after the production of the grating.

The method according to the invention advantageously ensures the stability of the grating constant and of all other parameters of the grating after the production of the grating on the optical conductor.

In one embodiment of the method according to the invention, the optical conductor is stress-free between the fixing points during the production of the grating, and, in another embodiment, the optical conductor is tensioned between the fixing points during the production of the grating.

The invention also provides an advantageous arrangement having a carrier body, an optical conductor and an optical grating, in particular a Bragg grating, the conductor being fixed at least at two fixing points, which are arranged at a distance from one another, on the carrier body, and the grating being formed on the fixed conductor between said fixing points, and which arrangement is characterized in that the conductor is durably fixed on the carrier body at the fixing points, and the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

The invention is explained in more detail by way of example in the description below, with reference to the drawings, in which:

Figures 1a to 1d show a starting stage, two intermediate stages and an end stage of an exemplary embodiment of the method according to the invention,

5

Figures 2a and 2b show, in side view and plan view, respectively, a Bragg grating sensor produced by the method according to the invention and serving for measuring a temperature,

10

Figure 3 shows, in plan view, a Bragg grating sensor produced by the method according to the invention and serving for measuring an acceleration, and

15

Figure 4 shows, in side view, a temperature-stable Bragg reference grating produced by the method according to the invention.

20

The figures are diagrammatic and not to scale.

In accordance with the starting stage of the method according to the invention and indicated in figure 1a, an optical conductor 1 is applied to a carrier body 2, which is illustrated in each case in side view in figures 1a to 1d, and is durably fixed at two fixing points 21, 21, which are arranged at a distance  $d$  from one other in the direction of a defined longitudinal axis 10 of the conductor 1, on the carrier body 2, thereby producing the first intermediate stage of the method according to the invention as indicated in figure 1b.

25

30

On the conductor 1 thus fixed, an optical grating 11 (see figure 1d) is produced between the two fixing points 21, 21. To that end, it is possible to use, for example, any of the methods described in the prior art.

35





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is diffracted at a grating structure 31 of the phase mask 3. Downstream of the grating structure 31 of the phase mask 3, a plus first order 32 of diffraction and a minus first order 33 of diffraction are produced, each of which respectively defines an interference fringe and which, taken together, form an interference fringe pattern 35. This fringe pattern 35 exposes the conductor 1 between the fixing points 21, 21 in such a way that the interference fringes defined by the borders 32 and 33 of diffraction periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1. On account of the photosensitivity of the conductor 1, a respective increase in refractive index arises in each exposing interference fringe.

After this exposure of the conductor 1, the end stage of the method according to the invention as illustrated in figure 1d has been produced, in which the optical grating 11 is formed between the two fixing points 21, 21 of the carrier body 2 on the conductor 1, said optical grating being defined by local refractive index increases 110 which periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1.

A particular advantage of the described use of the phase mask 3 is to be seen in the fact that the phase mask 3 can be applied directly on the carrier body 2 and, unlike before, the conductor 1 in the form of the glass fiber need not be brought into position at a distance before the phase mask 3. Moreover, this procedure advantageously ensures a very precise position of a Bragg wavelength and of the other parameters of the grating 11, for example a spectral width, a degree of reflection, etc. of the grating 11. It is advantageous that, since the grating 11 is already fixed by a carrier body 2, these parameters no

$\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}, \dots$

longer have to be set subsequently during installation.

In this way, it is also possible to produce two or more optical gratings 11 on the conductor 1 between the two fixing points 21, 21, to be precise at the same time

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and/or one after the other in time and/or spatially separate from one another and/or superposed on one another.

5 The fixing of the conductor 1 on the carrier body 2 at the two fixing points 21, 21 remains even after the production of the one or more gratings 11 and is not detached.

10 The optical conductor 1 is durably fixed on the carrier body 2 not subsequently but actually before the production of the one or more optical gratings 11.

The optical conductor 1 that is to be fixed on the  
15 carrier body 2 preferably does not yet have an optical grating, although at least one grating which is different from a grating 11 to be produced first may already be present on said conductor 1, but in that case it does not have the advantageous properties of  
20 the grating 11.

The optical conductor 1 is preferably an optical glass fiber, for example a monomode or multimode fiber and/or a core-cladding-glass fiber. The conductor 1 may also  
25 be an optical waveguide integrated on a substrate. The optical conductor 1 is preferably of elongate design in the direction of the longitudinal axis 10.

The optical conductor 1 can be held between the two the  
30 fixing points 21, 21 in such a way that it is stress-free during the production of a grating 11 between the fixing points 21. Preferably, the conductor 1 is freely suspended between the fixing points 21, 21 and the grating 11 is produced in the freely suspended  
35 conductor 1.

It is also expedient if the optical conductor 1 is stressed between the two fixing points 21, 21 during the production of the grating 11. Such prestressing is

*[Faint, illegible handwritten notes]*

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expedient because, as a result, the conductor 1 still remains extended even in the event of a mechanical load relief acting on it.

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The carrier body 2 may be designed not only for fixing the conductor 1, but also for realizing specific functions.

5 If the carrier body 2 serves only for fixing the conductor 1, it may be of simple, for example integral, design. By contrast, if it has to fulfil specific further functions, for example functions of a Bragg grating sensor, the carrier body 2 may be of more  
10 complicated, in particular composite, construction. Thus, by way of example, mechanical levers, actuators or elements having characteristic thermal expansion coefficients for temperature compensation may be part of the carrier body 2.

15 A particular advantage of the method according to the invention is that the conductor 1 can be connected to the carrier body 2, for example by bonding, soldering, collapsing, etc., without special consideration being  
20 given to conductor stress, room temperature and subsequently desired grating parameters of the grating 11. In the case of a conductor 1 in the form of a quartz glass fiber, for example, a temperature required for fixing the conductor 1 on the carrier body may be up to  
25 800°C, while a grating 11 to be produced after this fixing is already degraded from approximately 150°C and is even destroyed at higher temperatures. After the fixing of the conductor 1 on the carrier body 2 at a higher temperature, all that need be done is to wait  
30 until the temperature of the conductor 1 has fallen to below the temperature from which degradation or deformation of the grating 11 to be produced occurs.

The method according to the invention advantageously  
35 makes it possible generally to realize Bragg grating sensors for measuring a physical quantity, including, for example, a sensor for measuring a temperature, an acceleration, a force, an electrical current, an

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electric voltage, an electric field, a magnetic field,

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etc., and also, for example, a stable Bragg grating as optical wavelength reference, an accurate Bragg grating for application in telecommunications and/or a long period optical grating (Long Period Grating (LPG)) and applications thereof.

Figures 2a and 2b illustrate, in side view and plan view, respectively, an exemplary Bragg grating sensor produced by the method according to the invention and serving for measuring a temperature, figure 3 illustrates, in plan view, a Bragg grating sensor produced by the method according to the invention and serving for measuring an acceleration, and figure 4 illustrates, in side view, a temperature-stable Bragg grating produced by the method according to the invention as an optical wavelength reference.

Each of the two sensors and also the temperature-stable Bragg grating in each case has an arrangement having a carrier body 2, an elongate optical conductor 1 and a Bragg grating 11, the conductor 1 being fixed at two fixing points 21, 21, which are arranged at a distance d from one another, on the carrier body 2, and the grating 11 being formed on the fixed conductor 1 between said fixing points 21, 21, with the special feature that the conductor 1 is durably fixed on the carrier body 2 at the fixing points 21, 21, and the grating 11 is a grating which is produced after the durable fixing of the conductor 1 on the carrier body 2.

In the case of the sensor according to figures 2a and 2b, the carrier body 2 is preferably in one piece and is composed of quartz glass, for example. The conductor 1 is, for example, a glass fiber which is fixed durably to the body 2 between the two fixing points 21, 21, preferably under prestressing, and in which the Bragg grating 11 is formed between the two fixing points 21,



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21. The glass fiber 1 is freely suspended between the two fixing points 21, 21. To that end,

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the carrier body 2 has a cutout 20 on its side facing the glass fiber 1, said cutout being bridged by the fiber 1. A temperature-dependent change in refractive index and expansion of the fiber 1 leads to a measurable shift in the Bragg wavelength of the grating 11 with the temperature. The expansion of the fiber 1 with the temperature can be amplified by a suitably chosen material of the carrier body 2.

10 The arrangement of the sensor according to figure 3 differs from that of the sensor according to figures 2a and 2b essentially only through the presence of an inertial mass M. Otherwise, the sensor according to figure 3 structurally corresponds to the sensor according to figures 2a and 2b, and parts which are identical in both sensors are designated in figure 3 by the same reference symbols as in figures 2a and 2b.

In the sensor according to figure 3, the mass M is connected to the fiber 1 and exerts an expanding and/or contracting force on the Bragg grating 11, formed on the fiber 1, when the carrier body 2 is moved under acceleration.

25 In the case of the arrangement of the temperature-stable Bragg grating according to figure 4, the carrier body 2 is of composite rather than integral design. The composite carrier body 2 has a substrate body 2' and two sub-carrier bodies 2'', 2'' which are fixed on the substrate body 2' and separated from one another by an interspace 22'. On the two sub-carrier bodies 2'', 2'', the conductor 1, likewise comprising a glass fiber for example, is fixed at the two fixing points 21, 21 in such a way that one fixing point 21 is situated on one sub-carrier body 2'' and the other fixing point 21 is situated on the other sub-carrier body 2'', that the conductor 1 bridges the interspace 22', and that the grating 11 formed on the conductor 1 is arranged above

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the interspace 22'.

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The two sub-carrier bodies 2'', 2'' are fixed on the substrate body 2' in such a way that a section 20'', 20'' - adjoining the interspace 22' - of each sub-carrier body 2'', 2'' is not connected to the  
5 substrate body 2' and can freely expand and/or contract in the event of a change in temperature relative to the substrate body 2'.

The material of the substrate body 2' and the material  
10 of the two sub-carrier bodies 2'', 2'' are coordinated with one another in such a way that the interspace 22' between the sub-carrier bodies 2'', 2'' is narrowed and/or widened on account of a temperature-dictated expansion and/or contraction of the sections 20'', 20''  
15 of the two sub-carrier bodies 2'', 2''. By way of example, the sub-carrier bodies 2'', 2'' are composed of a material having a thermal expansion coefficient  $\alpha > 0$  and the substrate body 2' is composed of a material having a smaller thermal expansion coefficient  
20 relative to said coefficient  $\alpha$ , preferably a vanishingly small thermal expansion coefficient.

A narrowing of the interspace 22' brought about by a change in temperature counteracts an expansion of the  
25 conductor 1 and hence of the grating 11 brought about by said change in temperature. A widening of the interspace 22' brought about by a change in temperature counteracts a contraction of the conductor 1 and hence of the grating 11 brought about by said change in  
30 temperature.

The material of the substrate body 2', the material of the two sub-carrier bodies 2'', 2'' and the material of the conductor 1 are preferably coordinated with one  
35 another in such a way that the narrowing of the interspace 22' brought about by a change in temperature essentially exactly cancels the expansion of the conductor 1 and hence of the grating 11 brought about

[illegible]

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This is the case, for example, if the material of the sub-carrier bodies 2'', 2'' and the material of the conductor 1 essentially have the same thermal expansion coefficient  $\alpha > 0$  and if the thermal expansion

5 coefficient of the material of the substrate body 2' is vanishingly small relative to said coefficient  $\alpha$ .

Patent claims

1. A method for producing at least one optical grating (11), in particular a Bragg grating, on an optical conductor (1) the conductor (1) being fixed at least at two fixing points (21, 21), which are arranged at a distance (d) from one another, and the grating (11) is then produced on the fixed conductor (1) between said fixing points (21, 21), characterized in that the conductor (1) is durably fixed at the fixing points (21, 21) before the grating (11) is produced.
2. The method as claimed in claim 1, characterized in that the optical conductor (1) is stress-free between the fixing points (21, 21) during the production of the grating (11).
3. The method as claimed in claim 1, characterized in that the optical conductor (1) is stressed between the fixing points (21, 21) during the production of the grating (11).
4. An arrangement having
  - a carrier body (2),
  - an elongate optical conductor (1) and
  - an optical grating (11), in particular a Bragg grating,
  - the conductor (1) being fixed at least at two fixing points (21, 21), which are arranged at a distance (d) from one another, on the carrier body (2), and
  - the grating (11) being formed on the fixed conductor (1) between said fixing points (21, 21), characterized in that
  - the conductor (1) is durably fixed on the carrier body (2) at the fixing points (21, 21), and

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- the grating (11) is a grating which is produced after the durable fixing of the conductor (1) on the carrier body (2).



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Abstract

Method for producing an optical grating on an optical conductor and arrangement having such a grating and such a conductor

Method for producing an optical Bragg grating (11), on an optical fiber (1), the fiber being fixed at two fixing points (21, 21), which are arranged at a distance (d) from one another, and the grating (11) then being produced on the fixed fiber between said fixing points, with the special feature that the fiber is durably fixed at the fixing points before the grating is produced. An arrangement having such a grating and such a fiber is specified.

Figure 1d

1/2

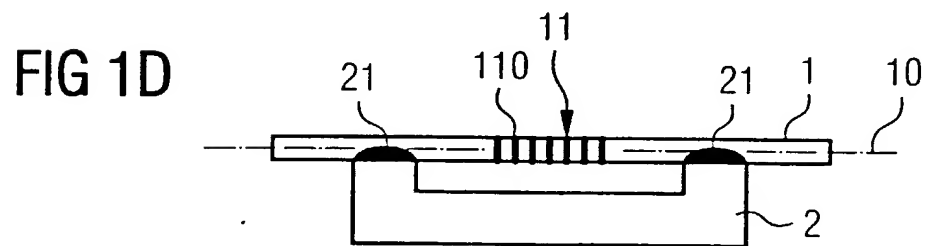
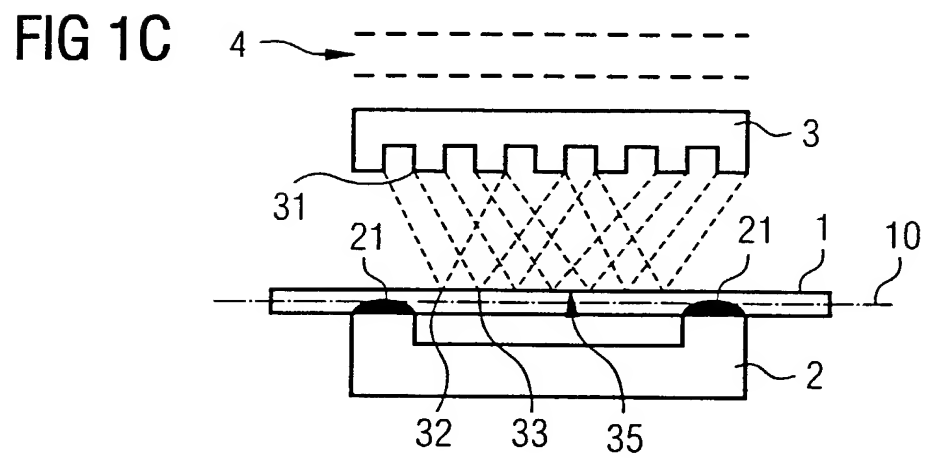
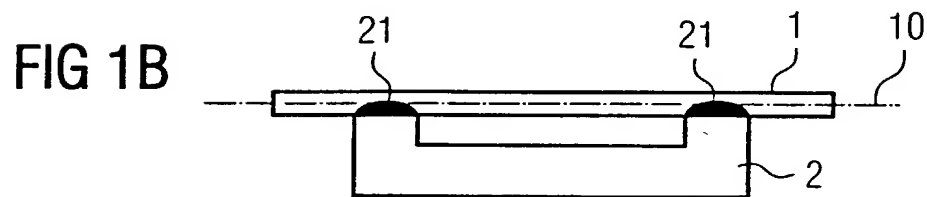
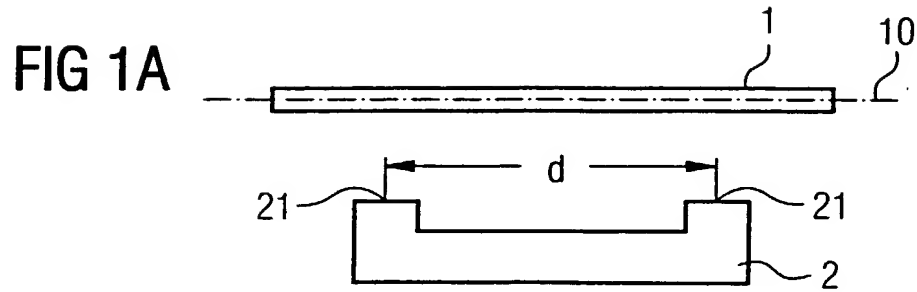


FIG 2A

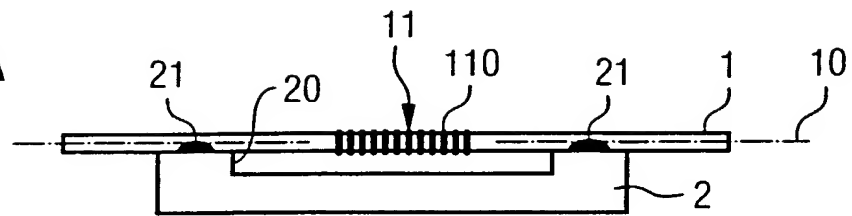


FIG 2B

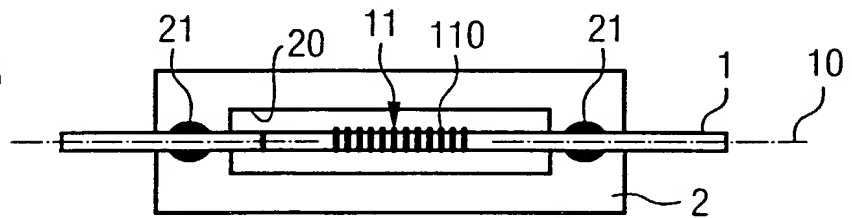


FIG 3

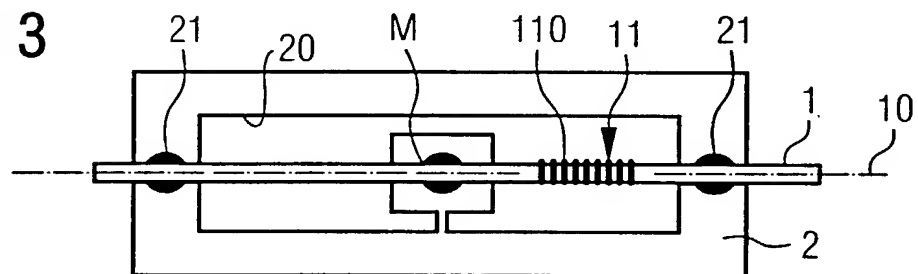
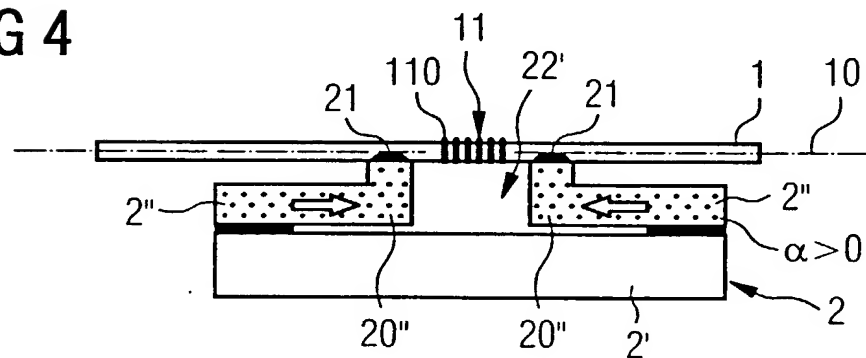


FIG 4



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deren Beschreibung

(zutreffendes ankreuzen)

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☒ am 06.09.2000 als

PCT internationale Anmeldung

PCT Anmeldungsnummer PCT/DE00/03078

eingereicht wurde und am \_\_\_\_\_

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Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

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As a below named inventor, I hereby declare that:

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I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

#### METHOD FOR PRODUCING AN OPTICAL GRATING ON AN OPTICAL CONDUCTOR AND DEVICE COMPRISING A GRATING OF THIS TYPE

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 06.09.2000 as

PCT international application

PCT Application No. PCT/DE00/03078

and was amended on \_\_\_\_\_  
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

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Prior foreign applications  
Priorität beansprucht

Priority Claimed

19943387.9

DE

10.09.1999

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☐

(Number)  
(Nummer)

(Country)  
(Land)

(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

Yes  
Ja

No  
Nein

(Number)  
(Nummer)

(Country)  
(Land)

(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

☐  
Yes  
Ja

☐  
No  
Nein

(Number)  
(Nummer)

(Country)  
(Land)

(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

☐  
Yes  
Ja

☐  
No  
Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1 56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/03078

(Application Serial No.)  
(Anmeldeseriennummer)

06.09.2000

(Filing Date D, M, Y)  
(Anmeldedatum T, M, J)

(Status)  
(patentiert, anhängig,  
aufgegeben)

pending

(Status)  
(patented, pending,  
abandoned)

(Application Serial No.)  
(Anmeldeseriennummer)

(Filing Date D,M,Y)  
(Anmeldedatum T, M, J)

(Status)  
(patentiert, anhängig,  
aufgeben)

(Status)  
(patented, pending,  
abandoned)

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(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

## German Language Declaration

Prior foreign applications  
Priorität beansprucht

Priority Claimed

19943387.9  
(Number)  
(Nummer)

DE  
(Country)  
(Land)

10.09.1999  
(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

☒ ☐  
Yes No  
Ja Nein

(Number) (Country)  
(Nummer) (Land)

(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

☐ ☐  
Yes No  
Ja Nein

(Number) (Country)  
(Nummer) (Land)

(Day Month Year Filed)  
(Tag Monat Jahr eingereicht)

☐ ☐  
Yes No  
Ja Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/03078  
(Application Serial No.)  
(Anmeldeseriennummer)

06.09.2000  
(Filing Date D, M, Y)  
(Anmeldedatum T, M, J)

(Status)  
(patentiert, anhängig,  
aufgegeben)

pending  
(Status)  
(patented, pending,  
abandoned)

(Application Serial No.)  
(Anmeldeseriennummer)

(Filing Date D,M,Y)  
(Anmeldedatum T, M; J)

(Status)  
(patentiert, anhängig,  
aufgeben)

(Status)  
(patented, pending,  
abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

## German Language Declaration

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**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

Customer No. 30596

And I hereby appoint

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(Name und Telefonnummer)

Direct Telephone Calls to: (name and telephone number)

Ext. \_\_\_\_\_

Postanschrift:

Send Correspondence to:

Harness, Dickey & Pierce, P.L.C.  
12355 Sunrise Valley Drive, Suite 350 20191 Reston, Va.  
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or

**Customer No. 30596**

<p><b>Voller Name des einzigen oder ursprünglichen Erfinders:</b> <b>MANFRED ROTHHARDT</b></p>	<p><b>Full name of sole or first inventor:</b> <b>MANFRED ROTHHARDT</b></p>
<p><b>Unterschrift des Erfinders</b> _____ <b>Datum</b> _____</p>	<p><b>Inventor's signature</b> _____ <b>Date</b> _____</p>
<p><b>Wohnsitz</b> <b>Kunitz, DEUTSCHLAND</b></p>	<p><b>Residence</b> <b>Kunitz, GERMANY</b></p>
<p><b>Staatsangehörigkeit</b> <b>DEUTSCH</b></p>	<p><b>Citizenship</b> <b>GERMAN</b></p>
<p><b>Postanschrift</b> <b>Vor dem Obertore 5</b></p>	<p><b>Post Office Address</b> <b>Vor dem Obertore 5</b></p>
<p><b>07751 Kunitz</b> <b>DEUTSCHLAND</b></p>	<p><b>07751 Kunitz</b> <b>GERMANY</b></p>
<p><b>Voller Name des zweiten Miterfinders (falls zutreffend):</b> <b>Michael Willsch</b> <span style="float: right;">2-00</span></p>	<p><b>Full name of second joint inventor, if any:</b> <b>Michael Willsch</b></p>
<p><b>Unterschrift des Erfinders</b> _____ <b>Datum</b> _____</p>	<p><b>Second inventor's signature</b> <i>Michael Willsch</i> <b>Date</b> <b>3.07.02</b></p>
<p><b>Wohnsitz</b> <b>Fürth, DEUTSCHLAND</b></p>	<p><b>Residence</b> <b>Fürth, GERMANY</b> <span style="float: right;">DEX</span></p>
<p><b>Staatsangehörigkeit</b> <b>DEUTSCH</b></p>	<p><b>Citizenship</b> <b>GERMAN</b></p>
<p><b>Postanschrift</b> <b>Schwabacher Str. 15</b></p>	<p><b>Post Office Address</b> <b>Schwabacher Str. 15</b></p>
<p><b>90762 Fürth</b> <b>DEUTSCHLAND</b></p>	<p><b>90762 Fürth</b> <b>GERMANY</b></p>

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).



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**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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And I hereby appoint

Telefongespräche bitte richten an:  
(Name und Telefonnummer)

Direct Telephone Calls to: (name and telephone number)

Ext. \_\_\_\_\_

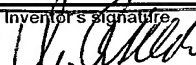
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12355 Sunrise Valley Drive, Suite 350 20191 Reston, Va.  
Telephone: +1 703 390 3030 and Facsimile +1 703 390 3020

or

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Unterschrift des Erfinders	Datum	Inventor's signature	Date
			22.07.2002
Wohnsitz <b>Kunitz, DEUTSCHLAND</b>		Residence <b>Kunitz, GERMANY</b> <span style="float: right;">DEX</span>	
Staatsangehörigkeit <b>DEUTSCH</b>		Citizenship <b>GERMAN</b>	
Postanschrift <b>Vor dem Obertore 5</b>		Post Office Address <b>Vor dem Obertore 5</b>	
<b>07751 Kunitz</b>		<b>07751 Kunitz</b>	
<b>DEUTSCHLAND</b>		<b>GERMANY</b>	
Voller Name des zweiten Miterfinders (falls zutreffend): <b>Michael Willsch</b>		Full name of second joint inventor, if any: <b>Michael Willsch</b>	
Unterschrift des Erfinders	Datum	Second Inventor's signature	Date
Wohnsitz <b>Fürth, DEUTSCHLAND</b>		Residence <b>Fürth, GERMANY</b>	
Staatsangehörigkeit <b>DEUTSCH</b>		Citizenship <b>GERMAN</b>	
Postanschrift <b>Schwabacher Str. 15</b>		Post Office Address <b>Schwabacher Str. 15</b>	
<b>90762 Fürth</b>		<b>90762 Fürth</b>	
<b>DEUTSCHLAND</b>		<b>GERMANY</b>	

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).